REMARKS

We are in receipt of the Office Action dated September 17, 2003, and the following remarks are made in light thereof.

Claims 1-40 are pending in the application. Pursuant to the Office Action, claims 1-35 stand rejected under 35 USC 103 as being unpatentable over Black, Jr. et al. 5,403,604 in view of Lawhon et al. 4,643,902 and Dechow et al. 4,522,836 and Puri 4,439,458. Claims 36-40 stand rejected under 35 USC 103 as being unpatentable over the combined references as is applied to claim 1-35 and further in view of Norman et al. 4,666,721.

In the Office Action, it was also noted that no references were found accompanying the Information Disclosure Statement for Huffman 3,801,717 and for the section from Citrus Nutrition & Quality, Steven Nagy and John A. Attaway, editors, Chapter 11, "Citrus juice processing as related to Quality and Nutrition", by Charles Varsel. Copies of both of these references accompany this response.

The invention of the pending application relates to a process for processing fruit juice with operating conditions that enhance the quality of the deacidified juice product. The process relates specifically to making low acid juices from not

from concentrate (NFC) juice. The deacidification process utilizes ion-exchange resin columns.

The inventive process is performed at refrigerated temperatures (i.e., not greater than about 45°F and preferably between about 35°F and 45°F) to produce a higher quality juice product. The quality of the resulting juice product is greatly enhanced by conducting the process at these low temperature levels, even though this would be expected to reduce the efficiency of the solid/liquid separation step and the ion exchange efficiency of the resin (see specification paragraph [0029]).

In addition, a portion of the non-deacidified juice is added back to the deacidified juice immediately upon its flow out of the resin columns in order to increase the acidity - - and lower the pH - - of the resulting blend to a level that discourages microbial activity. A pH of 4.5 or below is affected for this purpose. This is required because, at least in the initial stages of deacidification when the resin column is most effective the acidity level of the deacidified juice may be sufficiently low - -and the pH sufficiently high- -, undesirable microbial activity in the deacidified juice could occur. (See specification paragraph [0055]).

There are six independent process claims pending in the application, namely claims 1, 14, 22, 33, 34 and 35. Each of these independent claims includes either or both the steps of (a) cooling the initial juice flow to a temperature of not greater than about 45°F and maintaining the juice at or below this temperature throughout the process and (b) adding a portion of the initial single strength juice flow to the deacidified juice flow immediately after deacidification to lower the pH of the deacidified juice to a value that discourages microbial activity. None of the references relied on by the examiner for the rejection of claims 1-35 disclose either of these limitations.

Referring specifically to the Office Action, the examiner acknowledges that the claims differ from Black et al. due to the requirement of cooling the juice to 45°F. The examiner cites Lawhon et al. for disclosing that it is known that the aroma and flavor components and juices are easily volatized at a temperature above 40°C. The 40°C temperature disclosed in Lawhon et al. converts to 104°F. This is well in excess of that required by the pending claims.

The examiner also cites Lawhon et al. for disclosing that it is known to provide whatever acid reduction is desired, and that a reduced-acid RO (reverse osmosis) retentate can be mixed

in different ratios with normal acid RO retentate for use in juice reconstitution, citing column 11, lines 10-17. However, there is no suggestion in Lawhon et al. that a normal acid retentate be added to the deacidified juice immediately or promptly after deacidification in order to discourage microbial activity.

Accordingly, applicant submits that claims 1-35 are not obvious in view of the art cited by the examiner. Claims 36-40 are product claims that are dependent from claims 1, 14 or 22. Because claims 1,14 and 22 are patentable for the reasons set forth above, these dependent claims should also be patentable.

Accordingly, applicant submits that the pending claims are allowable over the prior art and request reconsideration and allowance of the application.

Respectfully submitted,

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Citrus Nutrition and Quality

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Florida Department of Citrus

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Citrus Juice Processing as Related to Quality and Nutrition

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There is much that can be said in favor of the consumption of fresh fruits and vegetables in the daily diet. In much of the world, citrus is consumed primarily as the fresh fruit, but in the United States processed products are consumed as the major source of citrus in the diet. The main staple of processed citrus juices in the U.S. is frozen concentrated orange juice (FCOJ).

Were it not for the processing of citrus fruits, this rich source of nutritious food, in the forms of juices and drinks, would be available to us for only limited periods of time throughout the course of any year. Processing techniques practiced today in the citrus industry ensure the availability of a continuous supply of citrus juices and their allied products to people in all regions of the United States and, indeed, in many parts of the world.

Our increased knowledge of nutrients in the food supply and how they are affected by processing has led to an increased awareness on the part of processors about the nutritional aspects and qualities of their products, and for a greater desire to improve processing techniques so that the consumer can derive maximum benefits from those nutrients. There has been an increased recognition in the food industry that we have some responsibility for the nutritional quality of our food supply. This awareness of responsibility has led to increased safeguards in processing so that not only the nutritional quality, but also the flavor acceptability is better retained in the processing of natural foods.

The increased awareness on the part of consumers about nutrition has led to an increased demand for citrus juices and products, a demand that is greater today than it has ever been. This has led to a tremendous growth within the citrus industry, and developing nations of the world that have climates suitable for the production of citrus fruits have benefitted tremendously from this consumer demand. Brazil is a prime example. The growth of the citrus industry in Brazil has been a great economic factor in

the welfare of its people. Brazil today is a major factor in the worldwide supply of citrus products and is second only to the U.S. in the production of citrus. This is evidenced in Table I, which presents data on citrus fruit production by specified countries (1). The overall growth of the citrus industry is, of course, fostered by improved economic conditions in many countries and evolving technologies that permit the production, storage, and shipment of citrus products over long distances. Refrigeration, new distribution methods, and new packaging techniques represent developments without which many people in the world could not enjoy the full flavor and nutrition of citrus products.

The unique and distinctive flavors of the citrus fruits and the general acceptability of these flavors by peoples throughout the world have also been factors contributing to the gr . of the citrus industry. Orange flavor is probably the most widely recognized and accepted flavor in the food and beverage industry worldwide. Because of its distinctive flavor and aroma it is used to flavor many foods and beverages and to aromatize many household products.

Grapefruit is less popular than the orange but perhaps more popular than the lemon relative to consumption of the juice. Popularity of grapefruit juice is increasing in many parts of the world, particularly in the United States and in Japan. How much its chimerical image as a dietetic food has contributed tc this increasing popularity is not known, but it undoubtedly has been a factor. Chilled and bottled grapefruit juices are growing in popularity whereas the usage of frozen concentrated grapefruit juice continues to grow, but at a slightly slower rate.

Lemon juice has many uses in the food industry that other juices do not have because of its uniquely different composition in relation to other juices, except perhaps lime. Large quantities of lemon juice are used to enhance food flavors and to deve' and balance the flavors of many food items, seafood being an .standing example. Possibly only sugar and salt are used more extensively in the development and enhancement of food flavors. Lemon juice has also gained in popularity because of technological advances that now permit the manufacture of concentrated juices and the production of a frozen concentrate for lemonade.

The flavor of lemon, contributed by the peel oil, is probably second only to orange flavor in overall popularity. The growth in market fcr the powdered soft drink mixes and the fruit drink mixes, particularly for lemon-flavored products, has increased the demand for lemon oil. Added to this is the increasing demand for lemon oils for use in the carbonated and noncarbonated soft drinks that are increasing in popularity worldwide.

TABLE I

Citrus Fruit: Production, by Selected Countries, of Principal Types, Crop Years 1976-77 through 1978-79 *(1)*

Country	Crop Years		
	1976-77	1977-78	1978-79 2/
	1,000 Metric Tons 1/		
	Oranges and Tangerines		
United States	10,144	9,256	8,725
Brazil	6,087	8,205	7,256
Japan	3,575	4,119	3,663
Spain	2,466	2,514	2,473
Italy	2,258	1,942	1,699
Morocco	784	1,055	992
Israel	968	949	975
Argentina	990	925	926
Mexico	1,283	750	783
Egypt	840	747	780
Turkey	671	735	780
Greece	533	455	629
South Africa	463	591	583
Australia	384	393	395
Cyprus	100	109	113
Chile	45	47	48
TOTAL	31,591	32,792	30,820
	Lemons		
United States	896	900	758
Italy	792	800	600
Brazil	371	363	367
Argentina	320	280	267
Turkey	278	280	250
Spain	220	313	239
Greece	190	194	175
TOTAL	3,067	3,130	2,656

1/ One metric ton is equivalent to 2204.6 pounds.
2/ Preliminary.

The Florida Crop and Livestock Reporting Service

TABLE II

U.S. Production of Oranges
Years 1973-78 (1)

Crop Year	Utilization of Production 1000 Metric Tons			% Tons Processed
	Fresh	Processed	Total	
1973-74	1613	6900	8514	81.0
1974-75	1951	7339	9290	79.0
1975-76	1803	7717	9519	81.1
1976-77	1680	7886	9567	82.4
1977-78	1598	7059	8657	81.5
1978-79*	1451	6854	8306	82.5
AVERAGE	1683	7292	8976	81.2

*Estimate

The Florida Crop and Livestock Reporting Service

1 Processing

Technological developments in high vacuum evaporation techniques have been responsible for the rapid growth of the domestic citrus industry. These techniques were developed and refined, for the most part, during World War II and they made possible the manufacture and production of many perishable foods and medicines. Most notable for the domestic citrus industry was the development of frozen concentrated citrus juices which was made possible by the development of these high vacuum evaporators

Frozen concentrated orange juice began to capture a real segment of the citrus market in 1948, and since then, its presence has been a dominant contributing factor to the increasing per capita consumption of citrus juices worldwide.

Processed orange products accounted for the usage of about 81% of the domestic orange crop between the years 1973 and 1978, as can be seen in Table II. Frozen concentrated orange juice in that period was by far the major product of the U.S. citrus industry, which is concentrated in 4 states; Florida, California, Texas, and Arizona, with Florida being the dominant factor in the industry.

About 94% of the Florida orange crop went into the production of orange juice products during the 6-year period, 1973-1978, and frozen concentrated orange juice accounted for approximately 81% of that usage. About half of the orange crop of Texas and about 40% of the Arizona crop were utilized in processed products, but only about one-third of the California crop was so utilized. The major portion of the latter crop went to the fresh fruit market. These data are summarized in Table III.

TABLE III

U.S. Production of Oranges by Region
6-Year Average 1973-1978 (1)

	1000 Metric Tons		
State	Processed	Total Production	% Processed
Florida	6614	7069	93.6
California	500	1550	32.3
Texas	129	235	54.9
Arizona	49	122	40.2
TOTAL	7292	8976	81.2

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Similar trends to those noted above exist in the domestic

TABLE IV

U.S. Production of Grapefruit
Years 1973-1978 (1)

Crop Year	Utilization of Production 1000 Metric Tons			% Tons Processed
	Fresh	Processed	Total	
1973-74	1023	1416	2439	58.1
1974-75	1038	1231	2270	54.2
1975-76	1193	1390	2583	53.8
1976-77	1034	1716	2750	62.4
1977-78	1101	1646	2747	59.9
1978-79*	1038	1452	2490	58.3
AVERAGE	1071	1475	2547	57.9

*Estimate

The Florida Crop and Livestock Reporting Service

grapefruit market, but that total market is only about 30% as large as that for oranges as seen in Table IV. Almost two-thirds of the Florida grapefruit crop goes to the production of processed products with frozen concentrated grapefruit juice accounting for about 35% of the processed juice. Chilled grapefruit juice accounts for about 12% of the processed juice, and that market segment is growing along with the bottled grapefruit juice market. Of the grapefruit produced in the other U.S. growing regions, California, Texas, and Arizona, more than half go to the fresh fruit markets. About 46% is processed. These data are shown in Table V.

TABLE V

U.S. Production of Grapefruit by Region
6-Year Average 1973-1978 (1)

State	1000 Metric Tons Processed	Total	% Processed
Florida	1173	1894	61.9
California	93	200	46.5
Texas	167	375	44.5
Arizona	42	78	53.8
TOTAL	1475	2547	57.9

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Table VI shows the average amounts of the Florida orange and grapefruit crops that went into processed products during the five-year period from 1973-1977. Frozen concentrates accounted for the major portion of the processed orange juice and about one-third of the processed grapefruit juice. Chilled orange juice in bottles and in dairy cartons accounted for a significant portion of the processed Florida orange crop and this is presently the fastest growing segment of the market. Chilled grapefruit juice is a growing market, but bottled, shelf-stable grapefruit juice is also experiencing major growth at the present time. Chilled grapefruit juice accounted for about one-eighth of the processed juice; but, canned and bottled grapefruit juices accounted for a major portion of the processed grapefruit juice as can be seen in Table VI.

TABLE VI

Processed Florida Citrus Products
6-Year Average 1973-1978 (1)

Product Category	Gallons Produced (000's)	Fruit Utilization (1000 Metric Tons)	% Of Processed Oranges	% Of Processed Grapefruit
Fr...n Concentrated Juice (Reconst. Basis)				
Orange	684,419	5644	81.0	
Grapefruit	40,912	405		34.5
Tangerine	4,700			
Blended	28			
Chilled Juice				
Orange*	125,517	978	14.0	
Grapefruit	16,244 (est.)	144		12.3
Canned Juice				
...ange*	40,393	278	4.0	
...rapefruit	66,328	588		50.0
Tangerine	68			
Blended	5,861			
Fruit Sections				
[illegible]				

*Includes Temples, Tangelos, and Honey Tangerines

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1.1 Juice Extraction

Citrus fruit is delivered to a processing plant in truckload quantities of 20,410 to 21,430kg or 20.4 to 21.4 metric tons. The fruit is unloaded, inspected for maturity and graded to remove unwholesome and damaged fruit, after which it is conveyed to fruit bins for storage. Fruit from the bins is washed with a detergent in a rotary brush washer, rinsed, then inspected and graded a second time to remove unwholesome fruit.

Juice extractors differ in design, but all are fast, rugged, easy to clean, and adjustable to accomodate fruit of different sizes. Prior to the invention of automatic extractors, the rotary juice press was in common use, and is still used commercially in many parts of the world, principally Italy, Spain, & South America.

The FMC In-Line Extractor is widely used in the domestic industry, most particularly in Florida, because it can effect simultaneous recovery of both juice and oil. A five-headed extractor can process from 325 to 500 fruit/minute. The extractor consists of a bottom cup, into which the fruit is fed, and an upper cup that meshes with the bottom as circular plugs are cut from the top and bottom of the fruit. The fruit in the bottom cup is compressed as the upper cup descends and juice and other fruit components are forced through the bottom plug into a strainer tube. The contents of the strainer tube, rag, seeds, and cell sacs, are squeezed between the top and bottom plugs resulting in almost complete extraction of juice and, in essence, a first-finishing operation since the plug (seeds, pulp, and peel) is separated from the juice. As the fruit is squeezed in the cup, peel oil expressed from the flavedo and small pieces of peel are washed into a conveyer by a water spray that surrounds the extractor cup. The valuable oil is recovered from the oil/water slurry.

Several types of Brown extractors are used in the citrus industry throughout the world. The Model 400 produces a juice that is low in peel oil content and high in juice quality. The fruit is halved and the juice removed by a rotating reamer that exerts pressure to effect extraction.

The Brown Model 700 Extractor operates in a manner similar to the Model 400 and produces juice of the same high quality with low oil content. It expresses the juice from about 700 fruit/min. compared to the 350 fruit/min. that can be processed by the Model 400.

A more sophisticated extractor, the Brown Model 1100, accepts [illegible] fruit, and has a processing [illegible] maximum juice yields. Fruit entering the extractor is halved by a stainless-steel knife and each half passes between a stainless-steel grid and a rotating disc. The juice is expressed in two stages equivalent to a light extraction (low pulp/low oil) and a hard extraction (higher oil/higher pulp), then flows to the bottom of the collector where it can be divided into two fractions.

The stainless-steel grid provides a coarse first-stage finishing operation simultaneously with the extraction. The juice flows through outlets at the bottom of the collectors and is conveyed to finishers.

1.2 Finishing Operations

In the finishing operation, seeds are removed from the juice and the pulp content is lowered. As with extractors, finishers vary in design. The two types most commonly used are the screw-type and the paddle-type. In both designs, separation is accomplished by a cylindrical perforated screen. Juice and a controlled amount of insoluble solids or fine pulp pass through the screen while the remainder of the solids is discharged at the of the finisher. The size of the screen perforations determines the size of the solid particles that remain with the juice. The juice extractor and finisher are employed in tandem to control the characteristics of the processed juice, but they also affect the juice yield and quality. The juice characteristics controlled by these operations include the pulp content and size, and oil content.

The finished juice is conveyed to blend tanks at which time the acidity and soluble solids level may be determined. If necessary, the juice can be deaerated and deoiled, dependent upon the product to be produced.

1.3 Evaporation

According to Cook (2), the first commercial orange concentrate was produced in Florida in 1938 on a low-temperature (20°-25°C) evaporator with 13 stages that operated under high vacuum.

Most of the evaporators used in the state of Florida prior 1947 utilized high temperatures and long residence times. se evaporators operated somewhere between 48.9° and 82.2°C (120°-180°F). Fruit solids remained in these evaporators for a minimum of 30 minutes; hence, the products produced on such evaporators were of poor quality and exhibited a strong heat processed flavor.

In 1946, the first commercial frozen concentrated orange juice was produced in a falling-film type evaporator operated at low temperature and high vacuum. This evaporator, installed by the Minute Maid Company (now The Coca-Cola Company Foods Division) employed a large steam jet pumping system to remove water vapor at high enough vacuum to maintain an operating temperature of about 18.3°C (65°F). The juice stayed in the evaporator for a long period of time, but the concentrate produced was far superior to that produced in high-temperature evaporators.

Low-temperature evaporators of the falling-film type were heavily utilized in the citrus industry through the 1950's and

and early 60's. The first high-temperature short-time evaporator was installed in Florida in 1959. This was a double-effect two-stage unit that employed some recirculation of steam. This research into evaporation principles led to the development of the present units that are used almost exclusively today in the domestic citrus industry. These units are known as TASTE (thermally-accelerated short-time evaporation) evaporators. Most of these units employ a single pass of juice, and they are composed of four to six effects with six or seven stages. The water removal capacity is normally 18,000 to 23,000 liters per hour, but some of the new units being constructed have water removal capacities of nearly 41,000 liters/hour.

Figure 1 illustrates the operating principles of a TASTE-type evaporator (2). Juice passes through the preheaters and is heated to the temperature of stabilization, about 205°-210°F (96.1°-98.9°C), to destroy enzyme activity. After stabilization, the juice passes through the nozzle at the top of the first stage where it flashes to a lower temperature, one that corresponds to the pressure at that point. The resulting mixture of juice and vapor is projected into the tube bundle in the first stage where further evaporation of water occurs as the juice passes down through the tubes.

This is not a falling-film evaporator because the liquid (juice) is mostly suspended in the vapor, and heat transfer is to the turbulent mixture. The exit velocity of the juice from the tubes is on the order of 20 to 100 meters per second (2).

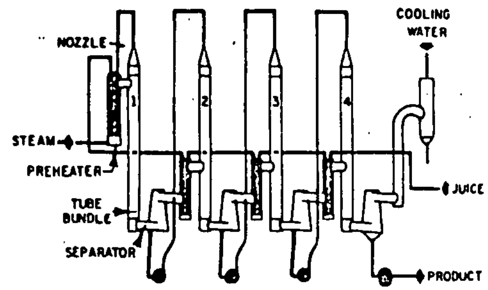
As it exits from the tubes, the liquid and vapor mixture travels into a centrifugal-type vapor separator, and the liquid then flows down the suction line to a heavy-duty pump.

On being pumped to the next stage, the liquid flashes through the nozzle and the mixture travels down the tube bundle as it did in the first stage. Vapor from the first-effect separator provides the heat for evaporation in the second stage.

The juice passes through additional stages, normally about seven in all, and after the last stage, the juice enters a chamber where it is flash cooled to about 10°C (50°F). After flash cooling, the concentrate, which will be at 65°-68°Brix, is pumped into drums or to a holding tank in one of the newly constructed tank farms that are becoming more prevalent in the domestic citrus industry.

In a four-effect evaporator steam is put into the first effect, where an effect relates to vapor flow, and the heat from that steam is used four times before condensation occurs in a barometric condenser. In theory, a four-effect evaporator will remove four liters of water per kilogram of steam usage, but in actual practice that water removal is about 3.4 l per kg of steam. Heat losses and the change in the heat of vaporization with temperature account for the difference.

A typical TASTE evaporator in use in a citrus plant is shown in Figure 2. The Coca-Cola Company Foods Division operates three



Institute of Food Technologists

Figure 1. Flow diagram for TASTE evaporator (2)

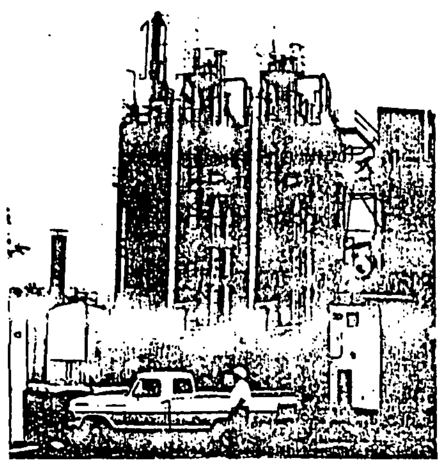


Figure 2. TASTE evaporator (courtesy of George Craddock)

citrus processing plants in the state of Florida, and in these plants are eight TASTE evaporators dedicated to the production of orange juice concentrate. Additional evaporators of the same type are also used for by-product production, e.g., citrus molasses and washed pulp solids. The eight evaporators used for the production of orange juice concentrate have a total rated capacity for water removal of 170,000 l per hour. The largest of these evaporators is rated at 36,400 l per hour of water removal.

Berry and Veldhuis (3) recently presented a comprehensive treatment of evaporators, and the reader is referred to that article for a more in-depth review.

1.4 Ion-Exchange Processing

Acid removal from citrus juices was first reported by Kilburn and Drager (4) in the early 1960's. They employed electrodialysis to remove citrate ion from citrus juices. Later, Berry and Wagner (5) used calcium hydroxide for precipitation of citrate in citrus juices.

A more recent process, i.e., acid reduction by anionic ion exchange, was developed at the Research and Development Laboratories of The Coca-Cola Company Foods Division in Plymouth, Florida.

Removal of citrate ion by an anionic ion-exchange process can be accomplished by exchange with hydroxyl ion and the subsequent formation of water, which is a component of juice and which can be removed by evaporation; hence, it should be preferable to a method that relies on the addition of a neutralizing substance to a citrus juice. The ion-exchange process is illustrated in the following equation:

$$3\ R^+ \cdot OH^- + C_6H_5O_7^{-3} \rightleftharpoons (R^+)_3 \cdot C_6H_5O_7^{-3} + 3OH^-,$$

where R^+ equates to a positively charged unit of the resin structure.

The ion-exchange resin employed in the acid reduction process is weakly basic and is approved for food use as prescribed in the food additive regulation 173.25(a)(14) in Title 21, Code of Federal Regulations (21CFR) (6).

Because the anionic resin is weakly basic, the retention of stronger acids is favored. As a result, when processing orange juice, the retention of citric acid is favored with respect to the weaker organic acids, ascorbic and folic, which are well-recognized nutrients in orange juice. Also, mass action favors the removal of citric acid.

The process permits the treatment of either bulk concentrate or freshly extracted juice. Freshly extracted juice is first stabilized at 175°-180°F (79.4°-82.2°C) then centrifuged in a high speed centrifuge to effect a pulp reduction to 2% to inhibit development of excessive back pressures in the column due to plug-

ging. This pulp can be re-added to the juice stream following acid reduction in the ion-exchange column. Bulk concentrate must first be diluted to about 15°Brix after which pulp reduction is accomplished by centrifugation. Stabilization of the dilute concentrate is not necessary because of its prior stabilization during concentration.

Acid reduction of orange juice is effected by downflow passage through the resin. Juice is passed through the column until the eluate (reduced-acid juice) drops to a pH below 4.6 as monitored by a pH meter. **This method assures minimal loss of ascorbic acid.**

The column eluate is discharged into an evaporator feed tank where its pH is adjusted to a maximum of 4.6 through the addition of freshly extracted, but untreated, juice or concentrated orange juice. At this time the pulp removed in centrifugation can also be re-added. This adjustment of pH ensures that no growth of pathogenic organisms can occur, and studies by independent laboratories have confirmed this finding.

Following pH adjustment of the acid-reduced juice, it is concentrated to 65°Brix in a TASTE evaporator.

1.5 Pasteurization and Packaging

The purpose of pasteurization, as it is practiced in the domestic industry today, is to destroy spoilage organisms, inactivate enzymes, or both. Heating to temperatures of only 150°F (65.6°C) will destroy most spoilage organisms but some heat resistant molds may require pasteurization temperatures as high as 210°F (98.9°C) for control.

Citrus juices that are pasteurized at the lower temperatures, 65-66°C, can undergo clarification, i.e., a process of separation that results in a lower layer of liquid and sediment and an upper layer of clear liquid. This process is brought about by the natural enzyme, pectinesterase, that occurs in citrus fruits. Studies have shown that processing of the juice at temperatures of 170-210°F (76.7-99°C) for a fraction of a second to 40 seconds will destroy the pectinesterase activity in citrus juices (7-10). The temperature necessary to stabilize the juice is pH dependent. Juices at higher pH require higher temperatures for stabilization. With the new high-temperature short-time techniques and equipment, stabilization can usually be effected in a fraction of a second. Flash pasteurization can be accomplished in either a plate-type or a tube-type heat exchanger.

Chilled juices, both orange and grapefruit, are increasing in popularity and, indeed, this market segment is presently the fastest growing in the industry. These products are pasteurized, cooled, and filled into paper cartons lined with a plastic or aluminum foil laminated with a plastic.

The chilled juice market experienced much of its initial growth through dairy processing and delivery systems, but today much of the product is processed in plants owned by companies involved in the citrus industry, even though the technology employed is based on that developed for the dairy industry. The products are pasteurized by the HTST (high-temperature short-time) process in which the juice is heated to a high temperature, on the order of 175°-180°F (79.4°-82.2°C) for a very short time, about 0.5 second. It is then cooled and filled into cartons at about 32°-40°F (0°-4.4°C). Such a process is not damaging to the flavor and texture of the juice and the resulting product has a very acceptable flavor and aroma.

Chilled products, which have shelf lives in the order of five to six weeks, are sold at refrigerated temperatures (4.4°-7.2°C) in retail outlets. Open code dating of these products ensures a supply of fresh product for the consumer at retail.

Some chilled products are packaged in glass containers, 32-fl. oz. and 64-fl. oz., but the dairy-type cartons account for the major segment of this market. Berry et al. (11) reported that the quality of these products remained high for long periods of time if maintained at 50°F (10°C) or lower, and products in glass exhibited better ascorbic acid and flavor stability than those in paper or plastic cartons. Higher temperatures led to more rapid deterioration of ascorbic acid and flavor.

Canned and bottled juices are pasteurized at relatively high temperatures (76.7°-90.6°C) and the containers are filled hot. The hot fill serves to sterilize the container and, in the case of a can, it is inverted for 60-90 seconds after seaming to sterilize the lid. The cans are then cooled to about 105°F (40.6°C) in a spin cooler or a spray cooler before being labeled and cased.

Bottles are filled in the same manner, but the caps are sterilized with steam or a chemical sterilant before being applied to the bottle. The filled containers are then cooled gradually in a spray cooler.

When freshly extracted juice is being filled into cans or bottles, the temperature of pasteurization must be sufficient to inactivate the natural enzymes, particularly pectinesterase. For orange juice, this temperature is somewhere between 185° and 195°F (85°-90.6°C) and is, to a degree, dependent upon the pH of the juice. Grapefruit juice, generally, need not be subjected to temperatures as high as are necessary to orange juice in order to achieve stabilization. The temperatures required for grapefruit juice are between 170°-189°F (76.7°-87.2°C). Joslyn and Sedky (7) showed that the heat inactivation of enzymes responsible for cloud instability in grapefruit juice was more rapid at pH 2.5 than at pH 4.0. Rouse and Atkins (9) and Pratt and Powers (12) corroborated these findings. Of course, with any juice the inactivation of enzymes is dependent upon both time and temperature. As the temperature of pasteurization is increased, the length of time in the pasteurizer can be decreased.

1.5.1 Aseptic Packaging

Canned and bottled citrus juices are examples of products that are packed aseptically, and these processes have been used in the industry for many years. One of the newer processes for aseptic packaging employs a paperboard package that is sterilized with hydrogen peroxide prior to the form, fill, and seal operation. This process, developed by Tetra Pak Ab of Lund, Sweden, is in use in many parts of the world, but it has not yet been approved by the U.S. Food and Drug Administration for domestic use.

The new packaging system developed by Tetra Pak is known as the Tetra Brik®, and is generally available in 1-l, 200-ml, and 250-ml sizes. The system is considered to be an alternative to metal and glass containers. The packaging material comes in roll st[illegible] form and is a 6-or 7-layer laminate. Polyethylene and al[illegible]inum foil offer the major barrier properties to the package.

The system enables heat sensitive products to be processed with minimal heat input. The processing temperatures employed are similar to those employed for the dairy-type paper cartons. The package integrity, when properly sterilized and maintained, is such that microbial reinfection is inhibited. Because oxygen can permeate the package along the longitudinal and lateral seams, it is not truly hermetic even though it does provide asepsis. One major advantage of the package is that it contains no headspace because the top seal is actually formed through a column of sterile product. This lack of headspace offers some protection, at least initially, to oxygen-sensitive products.

In many of the developing countries of the world, the Tetra Brik® system offers the only economical and practical package for juices and juice products (also milk).

The major disadvantages of the Tetra Brik® process are the slow line speeds (70 units per minute) and the limited mechanical and physical strength of the package. The latter makes careful h[illegible]ing and adequate secondary packaging quite essential.

2 Nutritional Quality of Citrus Juices

2.1 Vitamin C

Citrus fruits have long been noted as excellent sources of ascorbic acid (Vitamin C), which is the most abundant vitamin in the citrus fruits. Citrus fruits are also quite rich in the mineral element, potassium, and are often recommended for patients who must use diuretic drugs. Healthy adults require 60mg per day of Vitamin C and about 2.5g per day of potassium (13).

Atkins et al. (14) reported that most of the ascorbic acid that occurs in the orange is present as a constituent of the peel. Based on the weight of whole fruit, the juice contains about 25% of the total ascorbic acid content. The juice of the grapefruit contains only about 17% of the total ascorbic acid content on the same basis.

The ascorbic acid content of the juice of different citrus fruits varies considerably, and the content will vary with stage of fruit maturity, fruit variety, and climate. Soil conditions and fertilizing practices have only minimal effects if any at all (15). According to Ting and Attaway (16), oranges generally contain from 40-70mg/100ml of juice, whereas grapefruit, tangerine, and lemon juice contain between 20 and 50mg/100ml of juice.

The ascorbic acid concentration is high in immature fruit, and it decreases as the fruit ripen and increase in size, accor-ding to Harding et al. (17).

As with oranges, grapefruit exhibit an inverse relationship between ascorbic acid content and maturity. Metcalfe et al. (18) examined five varieties of grapefruit grown in six locations in the Rio Grand Valley of Texas and concluded that, although there were only small differences among the varieties, there were great variations in ascorbic acid content of the fruit from any given tree. These workers also reported a significant decrease in ascorbic acid content due to maturity. Ross (19) reported variations in ascorbic acid content of grapefruit from trees in different areas, as well as from trees in the same grove. He correlated the ascorbic acid content with acidity and reported that it increased with acidity.

A number of workers examined the effect of light exposure on ascorbic acid content and the general conclusion is that direct sunlight has a positive effect on its content; i.e., exposure to direct sunlight tends to increase the ascorbic acid content of fruit.

Long et al. (20) found that the ascorbic acid content of grapefruit was inversely related to their size. In Valencia oranges, Sites and Reitz (21) found a positive correlation between ascorbic acid and the soluble solids of fruit from the same tree.

As might well be expected, other citrus fruits exhibit the same type of seasonal decline in ascorbic acid content of the juice with maturity. Harding and Sunday (22) reported that the ascorbic acid content of tangerines may be 35mg/100ml of juice in the early season and as low as 10-15mg per 100ml if the fruit is allowed to overmature.

2.2 Other Nutrients of Dietary Significance

Other nutrients in orange juice that are of dietary significance, according to standards set by the U.S. Food and Drug Administration, i.e., they are present at a level of 10% or more of the U.S. RDA (Recommended Daily Allowance) per serving, are folic acid and thiamine (Vitamin B_1). The factor of significance (10% of the U.S. RDA per serving) is set forth in 21CFR 101.9(c)(7)(v)(6). A serving size for orange juice is generally regarded as six fluid ounces or 177ml.

Ting (23) reported values for thiamine in orange juice between 0.75 and 0.85mcg per gram of juice, and a survey of the literature indicates that other citrus juices contain lesser amounts. Analyses of orange concentrate by an industrial laboratory for our Citrus R&D Laboratories resulted in a value of 75mcg per 100g of reconstituted orange juice, in good agreement with the values reported by Ting (23). Adams (24) reports 91mcg/100g for reconstituted orange juice.

In the compilation of Adams (24), reconstituted grapefruit juice is reported to deliver about 38mcg of thiamine per 100g and tangerine juice (reconstituted) about 59mcg/100g. Per serving of 177ml, these values would be 170, 70, and 100mcg, respectively, for orange, grapefruit, and tangerine. With a U.S. RDA of 1.5mg, the percentage of the U.S. RDA of thiamine delivered by the juices would be 11%, 5%, and 7%, respectively.

Folic acid, generically described as folacin, is chemically known as pteroylmonoglutamic acid. There are several compounds that exhibit folic acid activity and they differ only in the number of glutamic acid residues they contain. These polyglutamates, as they are known, must be acted upon by the enzyme, conjugase, to release the folic acid for metabolic activity. A deficiency of this vitamin leads to megaloblastic anemia (25). Most evidence places the daily requirement for folic acid at about 50mcg per day of crystalline folic acid (26,27); however, the U.S. RDA for total food folacin is set at 400mcg for the adolescent, for adult males, and for non-pregnant, non-lactating females. The higher RDA is specified to allow for absorption of only 25% of folic acid activity in a manner comparable to the crystalline folic acid and to allow for a wide range of availability of the polyglutamate form (13).

Early work placed the folacin content of orange juice at between three and six micrograms/100ml (28). Later, Hurdle et al. (29) revised this to 20-45mcg/100g for orange products, and they also reported that canned grapefruit products contained about 11mcg/100g. More recent work by Streiff (30) indicated a folacin value of from 50-100mcg with ingestion of 100-125ml of orange juice. Grapefruit juice and tangerine juice were reported to have lower levels. Dong and Oace (31) reported a folacin value of 50mcg/100ml for orange juice, and a somewhat lower lever for grapefruit juice.

Ting et al. (32) reported an average folacin value for reconstituted Florida orange juice of about 45mcg/100ml. In our own studies, with analyses conducted by independent analytical laboratories, we have not seen values of that magnitude, but rather have observed values on the order of 26-33mcg/100ml of juice. These values would be on the order of 12%-15% of the U.S. RDA. Ting (23) has also reported that wide variation in the folic acid content occurs throughout the growing season and that the concentration increases as the season progresses.

2.3 Other Nutrients

A number of nutrients of lesser dietary significance are present in orange juice and other citrus juices. Measurable levels of Vitamin A, riboflavin (Vitamin B_2), niacin, pyridoxine (Vitamin B_6) and pantothenic acid have been reported in orange juice. The levels of these nutrients are generally in the range of 2-3% of their respective U.S. RDA's. For a more extensive review of these nutrients, one should consult Ting (23) and Araujo (33).

In addition to the vitamins mentioned above, citrus juices are a rich source of potassium. Even though potassium is an essential mineral in human nutrition, the U.S. Food and Drug Administration does not include it in its nutritional labeling program because it is widely distributed in foods. The Food and Nutrition Board of the National Academy of Sciences (13) has determined that healthy adults require about 2.5g of potassium per day. Based on the data of McHard et al. (34) a 6-oz. serving (177ml) of orange juice would provide about 0.29g of potassium. Values produced in our own laboratories would approximate a potassium content of about 0.4g per 177ml of orange juice. Ting (23) reports a potassium content of 0.30-0.4g per 177ml for orange juice.

Other mineral elements are present in citrus juices in measurable quantities. McHard et al. (34) reported on the trace element contents of Florida and Brazilian orange juice. They cited concentration ranges for 25 elements. Ting (23) reported that calcium, iron, phosphorus, magnesium, zinc, and copper are present in reconstituted FCOJ at levels equivalent to about 1% to 5% of their respective U.S. RDA's.

Phosphorus reportedly occurs in orange juice at levels of about 10-30mg/100g of juice (24,34,35), equivalent to 1.9-5.6% of the U.S. RDA; magnesium was reported at levels between 8-15mg/100 ml of juice by Birdsall et al. (36), whereas Ingwalson et al. (37) reported levels in reconstituted orange juice of 12-14mg/100g. McHard et al. (34) reported similar values. The maxiumum would be about 6.5% of the U.S. RDA per 177ml of orange juice.

Orange juice was reported to contain from 50 to 160mcg of copper per 100ml by Birdsall et al. (36), whereas others reported values in the range of 30-50mcg/100g (34,37), a maximum of 1.7% of the U.S. RDA, but possibly as low as 0.3% of the U.S. RDA.

Calcium has been reported at 6.5-15.4mg/100g of reconstituted orange juice (34,35,37). This level, which is 1.2% to 2.7% of the U.S. RDA, is not of any great significance. Likewise, iron, which has been reported at levels of 0.08 to 0.7mg/100g of orange juice (34,37) is not of any great nutritional significance because the level is only 0.8% to 7% of the U.S. RDA.

3 Effects of Processing on Nutritional Quality

Processing as it is practiced in the industry requires the input of heat to effect pasteurization, enzyme stabilization, and/

or concentration. Heat processing to achieve one of these three results would not be expected to have any detrimental effect on the mineral composition of citrus juices. These micronutrients should not be lost during processing; neither should they be degraded. The same cannot be said for the organic micronutrients, the vitamins, and the so-called macronutrients, carbohydrates, proteins, and fats, which supply energy as well as nutrition to the human body.

Citrus fruits are not regarded as good nutritional sources of fat based on 21CFR 101.9(c)(6) that the delivery of less than one gram of fat per serving is not of dietary significance (6). According to Adams (24), reconstituted FCOJ delivers about 0.2g of fat per 177ml; reconstituted frozen concentrated grapefruit juice about 0.2g/177ml. Tangerine juice may be slightly higher in fat content. According to Nagy (38), the lipids that occur in citrus juice contain high unsaturated/saturated fatty acid ratios (> 4).

The contribution of lipid oxidative products to off-flavor development has been studied by many workers, and a review of these studies has been presented by Nagy (38). It is generally agreed that the contribution of the lipid oxidative products to the flavor deterioration of processed citrus products is relatively minor when compared to the contributions by the products formed by the acid-catalyzed hydrolysis of flavoring oils and the products of Maillard browning (39,40).

Citrus juices and their products cannot be considered significant dietary sources of protein because the protein efficiency ratio (PER) of citrus protein is less than 20% that of casein (23, 41).

According to the regulations set forth in 21CFR 101.9(c)(7)(ii)(b), protein with a PER less than 20% that of casein is not of dietary significance (6).

The protein in citrus is generally associated with the solid portions of the fruit, i.e., the seeds, flavedo, albedo, chromatophores, and pulp. Some of these components find their way into the juice along with the available free amino acids during extraction and processing and storage. Studies conducted in our laboratories (42,43,44) and by others (45) have shown that reductions in the pulp content of juice slow the rate of browning.

According to Ting (23,41), a serving (177ml) of reconstituted FCOJ delivers about 19g of carbohydrate and 84 calories contributed primarily by the sugars, sucrose, glucose, and fructose. Adams (24), indicates that a serving of reconstituted FCOJ delivers 92 calories, whereas grapefruit and tangerine juice deliver 76 and 68 calories per 177ml, respectively.

Citrus juices contain both nonreducing (sucrose) and reducing (fructose and glucose) sugars. Mature oranges contain almost equal amounts of the two types and the reducing sugar content is composed of almost equal amounts of fructose and glucose. Grapefruit tend to have nearly equivalent amounts of reducing and nonreducing sugars, but at times, the reducing sugars tend to be slightly more dominant (16). In tangerines, the nonreducing sugar dominates except in immature fruit; in juice from mature fruit, sucrose may account for 60-65% of the total sugar content. In lemon juice, the reducing sugars dominate (46) and may account for about 90% of the total sugars.

The sugars, which contribute much to the acceptability of citrus juices, under adverse conditions can play a major role in the formation of off flavors that reduce the acceptability of the citrus juices and their products. The sugars, primarily the hexoses, can participate in "browning" reactions that cause darkening of the juice and these reactions give rise to components that are described generally as apricot-like or pineapple-like in flavor. In general, the more processed flavor that a citrus product exhibits, the less acceptable it becomes to the consumer.

Some authors have indicated that the sugar-amino acid reactions of the Maillard type are of minor importance in citrus juices because of the high acidities involved. Studies in our laboratories (42-44) would tend to indicate that, to the contrary, the amino acids and sugars are of more than just minor importance in the darkening of citrus juices. Huffman (42) treated citrus juices with cationic ion-exchange resins to remove amino acids, proteins, and the mineral cations, then restored the cations. The juices from which the free amino acids were removed were less subject to darkening and off-flavor development than were their respective controls after heating for long periods of time to temperatures near 100°C, then storing at room temperature. Juices were also dehydrated in a vacuum shelf dryer and on a chain belt dryer with less visible darkening than control samples. The ion-exchange treated juices were judged by sensory panels to be much more acceptable than untreated controls when presented as pasteurized juice or as dehydrated juice. Additional studies conducted in our laboratories (43) corroborated the findings of Huffman. In addition, lowering the pulp content of juice prior to dehydration decreased the tendency for juice to darken during the drying process. Seaver and Kertesz (47) reported that D-galacturonic and D-glucuronic acids, when heated alone or in the presence of amino acids, formed colored compounds at a rate exceeding that found with common sugars. They further reported that L-ascorbic acid formed colored compounds more rapidly than the sugars, but still at a slower rate than the uronic acids.

Curl (48), in a study conducted with a synthetic orange juice, reported that the loss of ascorbic acid occurred in the presence of citric acid and potassium citrate buffer alone, but that the losses were increased by the addition of the sugars, levulose, sucrose, and dextrose, in that order. He found that darkening of the synthetic juice occurred principally when both amino acids and sugars were present; and, the effect was even more pronounced by the presence of ascorbic acid.

Pruthi and Lal (49), in a study of different methods for

preserving and storing citrus juices, reported that the addition of 5% cane sugar to the juices accelerated the darkening and did not aid in ascorbic acid retention. Kato and Sakurai (50) studied the effects of ascorbic acid, organic acids, amino acids, and inorganic ions on browning in a model system. They determined that 3-deoxyglucosone and 5-hydroxymethylfurfural were formed by the action of organic acid on fructose (formed by inversion of sucrose). Browning, they reported, was affected by organic acids, amino acids, oxidized ascorbic acid, and the inorganic ions, Sn^{+4}, Fe^{+3}, Sn^{+2}, and Al^{+3}. These investigators reported that 3-deoxyglucosone and 5-hydroxymethylfurfural were intermediates in the browning of concentrated lemon juice that occurred when the concentrate was diluted to single-strength juice with a sucrose solution. They concluded that amino acids had a role in the wning (51).

.ulfrom et al. (52) studied the nonenzymic browning of dehydrated orange juice and concluded that 4-aminobutyric acid was of particular significance in the formation of colored products. The initial phase of the browning reaction led to a loss of D-glucose and 4-aminobutyric acid. Kampen (53) stored freeze-dried orange juice crystals and a synthetic mixture for 40 days at 50°C and monitored losses of total amino acids (73%), ascorbic acid (100%), citric acid (5.1%), and sucrose (4.4%). The orange juice crystals were discolored from Maillard browning, and several carbonyl compounds and furfural derivatives were identified as products of the reactions. Berry et al. (54) studied foam-mat dried instant orange juice stored at 70°F and at 85°F and reported that the stability of the product was improved by the use of more acidic juices, but adding acid, or removing sugar.

They reported an inverse relationship between stability of the instant orange juice and the pH of the orange concentrate dried.

Although the importance of the sugars in the browning of cit juices has been debated by many investigators, virtually all agree on the importance of ascorbic acid in this reaction. Joslyn (55) reported that ascorbic acid was the most reactive of the system, ascorbic acid-amino acid-sugar, that occurs in orange juice. Sugars, he reported, exercise a protective effect on the enzymic and nonenzymic oxidation of ascorbic acid; hence, both glucose and fructose are inhibitory to browning. The amino acids were reported to have an inhibitory effect in the early stages of the browning reaction, but in later stages, these components increased the rate of browning.

Moore et al. (56) reported that the decomposition of ascorbic acid in orange juice was directly associated with darkening. According to Curl (57), the development of off flavors in orange juices at 13–71% soluble solids was closely paralleled by the loss of ascorbic acid and by darkening. In mandarin juice, Aiba et al. (58) found that the rate of browning was related to the decomposition of ascorbic acid. Studies with the juice of natsudaidai (a Chinese citron) by Imai et al. (59) and others also implicated ascorbic acid as a major reactant responsible for browning. Imai et al. (59) reported that the free amino acids played an important role in the browning of the juice.

Clegg (60) studied the nonenzymic browning of lemon juice and reported that the phenomenon was attributable to ascorbic acid rather than sugar-amino acid condensations. She reported that furfural was produced during the development of browning, but did not consider that it played an important role in the aerobically-produced browning. In model systems that simulated lemon juice, she reported that amino acids in ascorbic systems were major contributors to browning (61).

It has been reported and is generally agreed that ascorbic acid in citrus juices can be degraded through aerobic and anaerobic pathways (53,62). The acid is quite sensitive to oxidation and dehydroascorbic acid is the primary oxidation product, though relatively unstable. It undergoes conversion to 2,3-diketogulonic acid. In addition to these oxidation products, furfural and hydroxyfurfural have been identified as products of the degradation of ascorbic acid (60,63,64,65). Bauernfeind and Pinkert (66) proposed pathways for both the aerobic and anaerobic pathways in aqueous media. In these pathways, shown in Figure 3, furfural can result from either mode of ascorbic acid destruction while hydroxyfurfural is a product of the oxidative system.

In processed citrus products, ascorbic acid loss can occur through aerobic or anaerobic mechanisms. The oxidation of ascorbic acid in orange juice was studied by Evenden and Marsh (67) and was reported to be a first order reaction whose rate was a function of temperature. In a very recent review, Nagy (65) reported that the degradation of ascorbic acid was best explained by a first-order reaction and that for grapefruit juice, the Arrhenius plot showed a linear profile for the temperature region 10-50°C. With orange juice, his data suggested that two different reaction mechanisms were operative with the kinetic change occurring at about 28°C. Between 10° and 27°C the rate of ascorbic acid loss doubled for each 10°C rise; from 27° to 37°C the rate quadrupled. The data of Nagy (65) also confirmed earlier data by Ross (68) and Lamb (69) that indicated for similar storage temperatures the loss of ascorbic acid was greater for orange juice than for grapefruit juice.

4 Processed Citrus Products

Of the 1978-79 domestic citrus crop, some 6,855,000 metric tons of oranges from a total of 8,340,000 metric tons went to the production of processed products. Of the 2,490,000 metric tons of grapefruit that were harvested, 1,510,000 metric tons were utilized in processed products. A similar picture can be painted for the other domestic citrus crops. It is easy to see that the market for processed citrus fruit in the U.S. is ex-

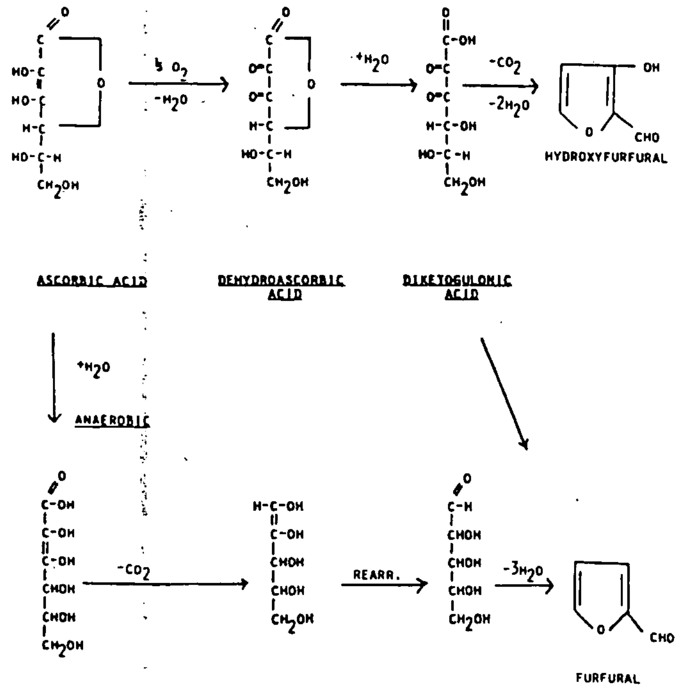


Figure 3. Possible ascorbic acid degradation pathways

tremely important to the citrus industry. Almost 95% of the Florida orange crop is utilized by processors in the production of juice products. Since the diets of domestic consumers contain processed products as their major source of citrus, it is reasonable to look at these products and how they are affected nutritionally by the processing techniques in practice in the industry.

4.1 Frozen Concentrated Juices

Frozen concentrated orange juice (FCOJ) is by far the most widely distributed of the processed citrus products. First marketed in the mid-1940's, it has grown in consumer acceptance until the present day, and to the point where its volume consumption exceeds the combined total for all other processed citrus products.

FCOJ and other frozen concentrated citrus juices are produced by the process outlined in Figure 4. Prior to evaporation the process includes extraction, finishing, and blending. In the evaporator, the juice may be concentrated to 45°Brix (% soluble solids) or higher; and, as a matter of routine practice, most of the evaporator pumpout (concentrate) is at 65-68°Brix. The concentrate can go to low-temperature storage or directly to processing for FCOJ. During the fruit processing season, cutback juice may be used to dilute the concentrate to 45°Brix. At other times, essence and water are used to prepare FCOJ. Berry and Veldhuis (3) reviewed this process in great detail.

The loss of ascorbic acid during extraction, finishing, and blending is minimal. Based on the data of Sale (70) and Hayes et al. (71), the loss should be no greater than 2%. Hayes et al. (71) prepared orange juice concentrates having 50-60% solids and reported a mean retention of 96.6% of ascorbic acid.

Ting et al. (32) collected samples of FCOJ from 23 manufacturing plants in Florida during 1973 and 1974 and analyzed them for selected nutrients, those specified by the U.S. Food and Drug Administration as being essential to human nutrition. The average nutrient content of FCOJ reconstituted to 12.8°Brix expressed as percent of the U.S. RDA is shown in Table VII along with the U.S. RDA's as specified by the Food and Drug Administration (6). Based on these data, it can be seen that FCOJ is of dietary significance with respect to Vitamin C (ascorbic acid), folic acid, and thiamine, i.e., it provides 10% or more of the respective U.S. RDA per 177ml serving.

Much has been written about the effects of processing, temperature, and storage conditions on the stability of ascorbic acid in citrus juices. On the other hand, little is known about the stability of folic acid under similar conditions. Chen and Cooper (72) studied the effects of temperature and oxygen and ascorbic acid on the thermal degradation of folic acid, and they reported that ascorbic acid increased the stability of the tetra-

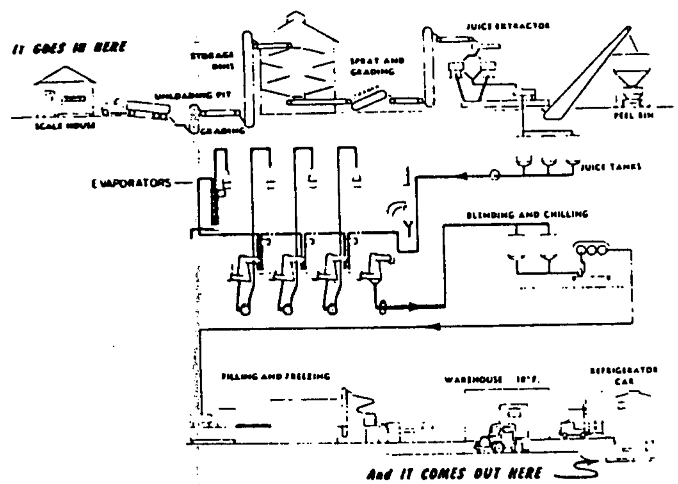


Figure 4. Flow diagram for frozen concentrated orange juice production (courtesy Adney Reed)

TABLE VII

Average Nutrient Delivery per Serving of Reconstituted FCOJ (12.8°Brix) in Relation to U.S. RDA

Nutrient	U.S. RDA(1)	Average % U.S. RDA/ 177ml FCOJ(2)
Vitamin A	5000 IU	1.4
Vitamin C	60 mg	131
Thiamine	1.5mg	9.8
Riboflavin	1.7mg	2.4
Niacin	20 mg	2.0
Calcium	1.0g	1.8
Iron	18 mg	1.1
Vitamin B_6	2 mg	4.9
Folic Acid	0.4mg	20.3
Phosphorus	1.0g	3.3
Magnesium	400 mg	4.9
Zinc	15 mg	0.7
Copper	2 mg	4.4
Pantothenic Acid	10 mg	3.3
Vitamin D	400 IU	---
Vitamin E	30 IU	---
Vitamin B_{12}	6 mcg	---
Iodine	150 mcg	---
Biotin	0.3 mg.	---

Source: 1) U.S. Food and Drug Administration (6).
2) Ting et al. (32).

hydro- and 5-methylfolic acid at 100°C. Their data indicated that the degradation of these folates at high temperature was due to an oxidative process that required the presence of molecular oxygen.

Floyd and Rogers (73) analyzed authentic samples of Florida orange juices and concentrates to determine the effects of concentration on chemical composition. They reported no significant effects of concentration on the chemical composition of orange juice concentrate as compared to single-strength juice. Setty et al. (74) reported that the nutrient content of mandarin orange juice when concentrated to 62°Brix and higher was very little affected.

Horton and Dickman (75) reported that the physiologically available ascorbic acid (ascorbic acid and dehydroascorbic acid) reconstituted orange juice was stable over a two-week period, both at 4°C and at room temperature. Aeration caused by blendorizing at high speed for two minutes had no effect on ascorbic acid stability.

Bissett and Berry (76) reported on the ascorbic acid retention in orange juice as a function of container type. They stored FCOJ in foil-lined cardboard, rectangular cartons and in polyethylene (PE)-lined fiber cylindrical cans for a year at -20.5°, -6.7°, and 1.1°C. At -20.5°C, the ascorbic acid retention was 93.5% in the foil-lined cartons and 91.5% in the PE-lined cans. Neither container proved effective above freezing due to microbial spoilage. The foil-lined carton was superior at 1.1°C, in that 89% of the ascorbic acid was retained after three months. In the PE-lined can, the retention was 44% after three months at 1.1°C.

Garcia (77) studied the effect of storage on 45°Brix and 54°Brix orange juice concentrates packaged in 6-oz. foil-lined, spiral-wound cans and in 200-ml foil-lined, rectangular cartons (Tetra Brik®). The latter were both cold filled and aseptically filled via high-temperature short-time pasteurization. These products were stored for one year at -17.8°, 7.2°, and 23.9°C. The aseptically-processed concentrates retained sterility throughout the course of the study and were stored at 7.2° and 23.9°C. The samples in 6-oz. foil-lined composite cans and those cold filled into the 200-ml rectangular packages were stored only at -17.8°C because they were not aseptically packed and were subject to microbial spoilage.

Figures 5 and 6 show the ascorbic acid retention in the 200-ml packages as a function of time. The data for the 6-oz. composite can are not shown because the ascorbic acid retention in these packages was similar to but just marginally poorer than was the retention in the 200-ml packages at -17.8°C. This marginal difference was attributed to the presence of some headspace oxygen in the 6-oz. cans which resulted in the loss of slightly more ascorbic acid.

At -17.8°C, the retention of ascorbic acid over 12 months

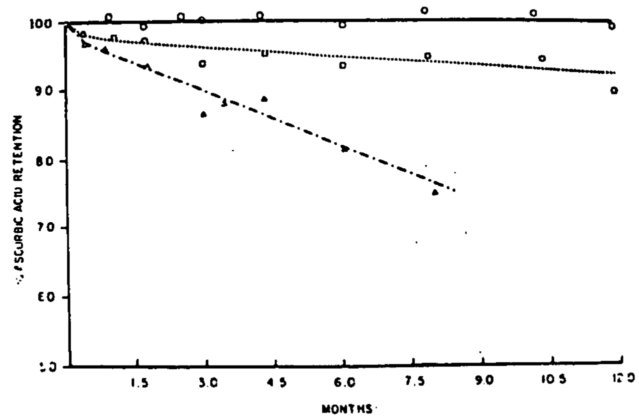


Figure 5. Ascorbic acid retention in 54° Brix concentrated orange juice as a function of storage temperature ((○) −17.8°C; (□) 7.2°C; (△) 23.9°C)

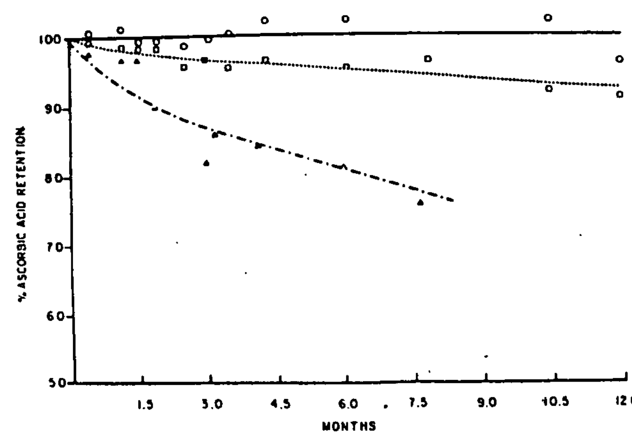


Figure 6. Ascorbic acid retention in 45° Brix concentrated orange juice as a function of storage temperature ((○) −17.8°C; (□) 7.2°C; (△) 23.9°C)

exceeded 97% in the 200-ml packages and 94% in the 6-oz. composite cans.

The ascorbic acid retention in both the 45°Brix and 54°Brix concentrates stored at 7.2°C were very similar over 12 months. The loss of ascorbic acid amounted to about 8% to 10% over the storage period.

At 23.9°C, the 45°Brix concentrate initially exhibited a more rapid loss of ascorbic acid than did the 54°Brix concentrate, but at the end of eight months both had lost about 25% of their starting ascorbic acid. The more rapid loss of ascorbic acid may have been caused by the amount of dissolved oxygen in the 45°Brix concentrate initially. It may have been the result of more rapid diffusion of oxygen into the lower °Brix concentrate [illegible]e it entered the package along the longitudinal seam and at [illegible]e corners. Neither factor was measured.

As might have been expected, flavor deterioration followed the same pattern as did the degradation of ascorbic acid, i.e., the concentrates at 23.9°C deteriorated in flavor acceptability more rapidly than did those at 7.2°C; those at 7.2°C deteriorated at a faster rate than did those stored frozen. The products stored at 23.9°C remained acceptable in flavor for about six months; those at 7.2°C remained acceptable for eight to ten months. At -17.8°C, the products were still acceptable after a year of storage.

Packages of the type used in this study by Garcia are presently used in many parts of the world for the packaging of milk, juices, and juice products. Brik Pak, Inc., a subsidiary of Tetra Pak Ab has petitioned the Food and Drug Administration for approval to use the Tetra Brik® package in the U.S., but a final decision regarding their petition is still pending.

Frozen concentrated grapefruit juice is produced in essentially the same manner as FCOJ. Prior to evaporation, the juice stabilized at 66° to 88°C to prevent gelation and clarification during storage. As is done in the manufacture of FCOJ, coldpressed grapefruit peel oil is added to the grapefruit concentrate to enhance its flavor. Essence, the volatile water soluble flavor from the fruit, may be added during the manufacture of a grapefruit concentrate, but this system of flavors does not seem essential to high flavor quality. This is contrary to what is generally found with FCOJ where essences do enhance flavor quality (78).

4.2 Reduced-Acid Frozen Concentrated Orange Juice

Interest in reduced-acid citrus juices originated in the early 1960's when Kilburn and Drager (4) employed electodialysis to remove citrate ions from juice. The Florida Department of Citrus tested the redyced-acid concept with consumers at the New York World's Fair in 1965, and followed this test with a national consumer survey in 1972. The Coca-Cola Company Foods Division conducted an independent consumer survey in 1973, and all of the studies indicated substantial consumer interest in reduced-acid citrus juices. After further testing with consumers in which products were tested in homes, the Foods Division was granted a permit from the U.S. Food and Drug Administration and the Florida Department of Citrus to manufacture the product and to distribute it in interstate commerce. Later the FDA was petitioned to establish a new standard of identity for reduced-acid frozen concentrated orange juice. The issuance of that standard is still pending.

A reduced-acid frozen concentrated orange juice is presently being test marketed by The Coca-Cola Company Foods Division. This product is produced by blending regular concentrated orange juice with acid-reduced concentrate in proportions that will result in a final frozen concentrated orange juice with a Brix/acid ratio between 21 and 26 to 1; the precise blend being dependent on the Brix/acid ratios of the two concentrates employed. After blending, the concentrate is adjusted to 45°Brix through the addition of water and essence. Coldpressed orange oil is added for good flavor quality. The product is then canned and stored at -17.8°C.

The fates of the nutrients of orange juice were naturally of concern in the process of producing an acid-reduced orange concentrate, so many studies were conducted to ascertain the levels of the major nutrients before and after processing. The major concerns were in regard to ascorbic and folic acids, since these components might well be removed during the ion-exchange process to remove citrate ion.

Since the anionic resin employed is weakly basic, the retention of stronger acids is favored with respect to the weaker acids, ascorbic and folic. Also, because of the law of mass action, the removal of citrate ion is favored over ascorbate and folate.

The change in the ascorbic acid concentration of juice during acid reduction processing is illustrated in Figure 7. Some ascorbic acid is initially retained by the resin but it is later replaced by the stronger acid, citric, as the exchange capacity of the resin is depleted. This initial reduction in ascorbic acid is on the order of 15%, but as the column is exhausted this acid is replaced by citric and it is eluted in the juice stream. Near the end of treatment, the ascorbic acid level rises to its initial level and even exceeds it as that which was initially held by the column is replaced by citrate.

It can be seen in Figure 7 that some ascorbic acid can be lost if the ion-exchange resin is not completely exhausted during processing. When the column is exhausted this loss of ascorbic acid is minimized.

Ascorbic acid loss in acid-reduced juices never exceeded 10% except in cases where the ion-exchange resin was not completely exhausted and generally it was in the range of 3% to

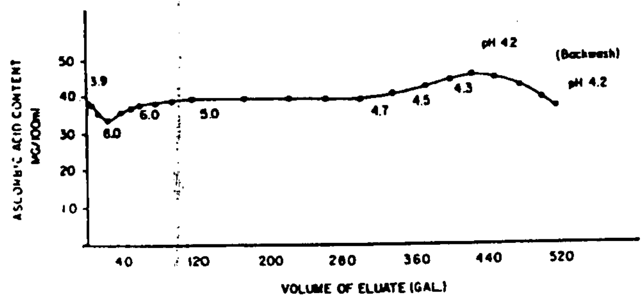


Figure 7. *Change in ascorbic acid level during acid reduction by ion exchange*

7%. When the acid-reduced concentrates are blended with regular (untreated) orange concentrates to produce a retail product, the reduction in ascorbic acid levels should not exceed 3%; hence, the reduced-acid FCOJ will have an ascorbic acid level within the range of acceptable levels of regular FCOJ. The changes in ascorbic acid levels during acid reduction are generally no greater than those that might be experienced in normal juice and concentrate processing.

The analysis of folic acid is accomplished by a microbiological assay employing either one of two organisms, L. casei or S. faecalis. The latter organism reportedly gives more reproducible results but the former gives greater sensitivity. Generally, for normal levels of folate in orange juice, the L. casei method is the one of choice; however, its reproducibility is probably only on the order of ± 20%.

Our Citrus R&D Laboratories are not equipped for the routine analysis of folic acid so samples of acid-reduced orange concentrate were submitted to two independent laboratories, and they were also analyzed at the Citrus Experiment Station in Lake Alfred, Florida. Typically, samples of freshly extracted orange juice or orange juice concentrate diluted to 12.8°Brix were found to contain between 21 and 30 micrograms (mcg) of folic acid per 100ml of juice. As a general rule, acid-reduced orange juice, after pH adjustment, going to the TASTE evaporator contained folic acid levels equivalent to the starting juice or concentrate. Some typical analyses are shown in Table VIII.

The total nitrogen content of acid-reduced orange juice was not different from that of regular orange juice, but the free amino acids, as determined by formol titrations, were 3% to 4% higher in the acid-reduced juice. This slight increase in free amino acids may have resulted from some protein hydrolysis during the ion-exchange process.

Other nutrients were measured in acid-reduced orange juice and, for the most part, no significant changes were observed from what would be expected for freshly extracted juice or reconstituted FCOJ. Some data relative to the other nutrients are presented in Tables IX and X.

Based on a review of all the data gathered for reduced-acid FCOJ, it is apparent that any changes that do occur are of an insignificant nature and do not alter the nutritional quality of the processed orange juice. The product of commerce is of equivalent quality to the more popular product, frozen concentrated orange juice.

4.3 Chilled Citrus Juices

The market for chilled citrus juices is one of the fastest growing segments of the domestic retail market, and now is second only to FCOJ in terms of volume consumption. Since its inception in the mid-fifties, this category for processed citrus juices has

TABLE VIII

Folic Acid Content of Acid-Reduced Orange Juice

Description	Folic Acid Content (mcg/100ml)
Diluted Orange Juice Concentrate (12.8°Brix)	
Before Centrifuge (Pulp Removal)	26.3
After Centrifuge	30.7
IE Column Eluate (Juice)	21.4
After pH Adjustment*	32.9
Fresh Orange Juice	
Before Centrifuge (Pulp Removal)	21.6
After Centrifuge	21.3
IE Column Eluate (Juice)	16.5
After pH Adjustment*	22.0

*pH Adjusted to 4.5 by Addition of Juice and Pulp Removed by Centrifugation

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TABLE IX

Nutrient Content of Acid-Reduced Orange Juice

Nutrient	Nutrient Content/100ml of 12.8°Brix	
	Before I-E Column	After I-E Column
Vitamin B_1 (Thiamine)	0.14 mg	0.13 mg
Vitamin B_2 (Riboflavin)	0.085mg	0.072mg
Vitamin B_6 (Pyridoxine)	0.080mg	0.086mg
Niacin	0.68 mg	0.69 mg
Pantothenic Acid	0.29 mg	0.44 mg

TABLE X

Range of Mineral Content of Acid-Reduced Orange Juice

Mineral	Mineral Content (ppm)	
	Reported in Orange Juice(1)	After I-E Column
Sodium	2- 24	7- 35
Potassium	1500-2300	1945-2346
Calcium	50- 150	66- 144
Magnesium	90- 130	115- 138
Iron	0.2- 5.0	0.3- 1.4
Copper	0.25-0.33	0.3- 0.4

(1) As compiled from the literature.

experienced some major changes in packaging, and its future probably holds much of the same.

Chilled juices being marketed domestically are prepared either from freshly extracted juice or from concentrate that has been bulk shipped to a packaging site then reconstituted to single-strength juice.

Early chilled juice products were packaged in paper milk cartons and in polyethylene containers. These containers have largely been supplanted by glass bottles and more recently by polyethylene-lined paper cartons. In some cases, the cartons also contain a layer of aluminum foil between the paper and polyethylene. These containers are not hermetic and in many cases are not sterile; thus, even though the juice is pasteurized, the final product is perishable. It may become recontaminated by the package, although this does not often occur. The major problem encountered with these cartons is that they permit transfer of oxygen into the product with the resultant flavor and ascorbic acid degradation; hence, they have relatively short shelf lives. Open code dating, in common practice in the food industry today for perishable products, indicates that the shelf life of a citrus juice in a dairy-type container is in the order of 28 to 42 days depending on the juice and the construction of the juice board in the package. These products must be distributed through channels that allow for refrigeration. Primary storage (i.e., after packaging and before being delivered to the retail outlet) temperatures near 0°C are often specified.

Juices in glass bottles are considered commercially sterile

because the bottles and caps are sterilized and the juice is pasteurized then cooled before the containers are filled. Since there is no oxygen transfer that can occur, more prolonged shelf stabilities are generally realized. These products, when distributed through refrigerated channels, will maintain good flavor acceptability for periods up to ten months. Ascorbic acid stability through this period is also good. At times, such products are distributed at ambient temperature; hence, the shelf life as measured by flavor acceptability and ascorbic acid stability is shortened considerably, perhaps by as much as four to five months.

Berry et al. (11) and Bissett and Berry (76) stored single-strength orange juice (SSOJ) in glass, polyethylene, and polystyrene bottles and in wax-coated cardboard cartons at several temperatures for various periods of time. They concluded that chilled SSOJ in glass containers retained a high level of ascorbic acid for 32 weeks when stored at temperatures not exceeding 10°C. Juices stored in the plastic bottles and in the wax-lined cartons lost 80% of their ascorbic acid in three to four weeks. They concluded that the acceptable shelf life for juice in polystyrene bottles and in waxed cartons was two to three weeks at normal refrigeration temperatures.

Squires and Hanna (79) examined 17 brands of reconstitued orange juice in plastic-coated cardboard containers that were purchased at the retail level then stored at 4°C. Their data indicated that the ascorbic acid contents of these chilled orange juice samples decreased at a rate of about 2% per day. They concluded that the acceptable shelf life for these products was 20 days, at which time the ascorbic acid retention had decreased by about 39% to a level of 28mg/100ml of juice (49.6mg/177ml serving or 82.6% of the U.S. RDA).

Our Technical Department (80) conducted a study in which 80 retail samples of orange juice from concentrate packaged in 32-oz. and 64-oz. plastic-lined cartons were picked up from 14 different retail outlets. The mean age of all samples was 20.2 days; 22.3 days for samples in 32-oz. containers and 18.5 days for samples in 64-oz. containers. The ascorbic acid content of each sample was determined and the average for all samples was 35.2mg/100ml (62.5mg/177ml or 105% of the U.S. RDA per serving). The samples in 32-oz. cartons averaged 33.1mg of ascorbic acid/100ml (58.7mg/177ml or 98% of the U.S. RDA); the samples in 64-oz. cartons averaged 37.7mg/100ml (66.8mg/177ml or 111% of the U.S. RDA). Of all samples analyzed, 53% delivered at least 100% of the U.S. RDA of ascorbic acid per 177ml serving, and all delivered at least 75% of the U.S. RDA of ascorbic acid per serving.

These data would suggest that, although there is some loss of ascorbic acid during the normal shelf life of orange juice in plastic-coated paper cartons, this processed product represents a significant source of ascorbic acid in the diet of any consumer at any time during its dated life expectancy (as indicated by the

date code on the carton). Ninety-six percent of the samples delivered at least 28mg of ascorbic acid per 100ml of juice, the criterion set forth by Squires and Hanna (79).

Paper cartons with an aluminum-foil barrier between the paper and plastic are used for the distribution of some chilled products. Because of the foil barrier, products in these cartons exhibit better ascorbic acid retention than do the plastic-lined cartons. As an example, grapefruit juice stored in such cartons retained 74% of its ascorbic acid over a 40-day storage period at 4.4°C. The rate of ascorbic acid loss was 0.7% per day. Grapefruit juice in a plastic-lined container lost 1.5% of its ascorbic acid per day when stored under similar conditions.

4.4 Canned Juices

Canned grapefruit juice still represents the major segment of the market for processed grapefruit, as can be seen in Table VI. Canned orange juice, on the other hand, represents only a very small percentage of the orange crop that is processed, and its share of the total market for processed oranges is still on the decline. The greater acceptability of FCOJ and chilled orange juice and the increasing growth of the chilled orange juice market segment are the major reasons for the declining market for canned orange juice.

In the infancy of the market for processed citrus juices, the canned single-strength juices were the first products to be widely distributed. In today's market, the main strengths of canned orange juice are its perceived convenience, economy, and ease of storage. Chilled orange juice, on the other hand, is generally regarded by the consumer as being more like fresh orange juice.

Canned orange juice is normally prepared from freshly extracted juice; however, that may not be the case with grapefruit juice. Since the growth in popularity of bottled grapefruit juice, a sizeable portion of that market consists of grapefruit juice from concentrate, as is also the case with chilled grapefruit juice.

In the preparation of canned orange juice, the juice is extracted from fruit, finished and blended to achieve the best possible physical characteristics of the juice, i.e., color, cloud, sweetness, and acidity. After blending the juice is deaerated, deoiled, pasteurized, and canned.

Deaeration is utilized to remove dissolved oxygen from the juice, thereby retarding the oxidation of ascorbic acid and flavor changes that may result from a combination of oxidative browning and oxidative changes in the flavoring oils (81). Deoiling can be accomplished by flash evaporation under vacuum (82), after which the oil content can be readjusted to achieve an acceptable level, which should not exceed 0.035% v/v for grade A orange juice and is generally below 0.020% v/v. For grapefruit juice,

the level is usually lower than 0.015% v/v.

Pasteurization and stabilization of orange juice are generally accomplished by heating to 88-93°C for up to 40 seconds. Grapefruit juice can be pasteurized and stabilized at lower temperatures, perhaps 71-82°C, because of its higher acidity. Following pasteurization the juice is filled into cans or bottles.

Flavor changes that occur in citrus juices are the result of heat input into the product over time; i.e., they are a function of temperature and time. It is for this reason that canned and bottled juices are generally less preferred by consumers than other processed citrus juices, e.g., frozen concentrates or chilled juices. The canned juices receive more heat input during pasteurization and they remain at relatively high temperatures for extended periods of time because they are discharged from the water coolers at temperatures near 40°C to facilitate drying and to inhibit rusting of the cans. It is well known that the rate of flavor deterioration increases with temperature, so canned juices are stored at a temperature as low as is economically practical before distribution at the retail level to extend their shelf life as much as possible.

Ross (68) studied the flavor deterioration and ascorbic acid retention in canned juices, and he concluded that storage temperature was very important to ascorbic acid retention. Further, he found that flavor acceptability was dependent on both time and temperature of storage and that it roughly paralleled ascorbic acid retention. Between 10° and 27°C, the rate of ascorbic acid degradation doubled for a 10° rise in temperature; between 27° and 37°C the rate quadrupled. Studies by Nagy and Smoot (83) and Nagy (65) corroborated these results and further confirmed the finding that ascorbic acid loss is greater in orange juice than in grapefruit juice when stored at similar temperatures.

Moore (84) reported that the ascorbic acid retention was [illegible]% for bottled orange juice and 93.2% for canned orange juice stored at 4.4°C for 18 months. At 24.4°C, the ascorbic acid retentions after 18 months were 50.9% and 59.8% for bottled and canned orange juice, respectively. This effect of container type was further demonstrated in studies by Riester et al. (85), Curl (48), and by Moore et al. (86). These studies showed greater losses of ascorbic acid in enamel-lined cans than in plain tin cans. The difference was attributed to the protective effect of the tin, in that oxygen reacted with tin in one case and with ascorbic acid in the other.

A composite, flexible package in broad use throughout much of the world today is the aseptic Tetra Brik®, a rectangular package of laminate construction containing six or seven components with paper as the primary one. Juices are distributed and retailed in parts of Europe, Asia, South and North America in 200- and 250-ml and in 1-liter Tetra Brik® packages, normally at ambient temperature.

Studies were conducted in our laboratories in which single-strength orange juice from concentrate was aseptically packed into liter Tetra Brik® packages and also was hot-filled into 1.36-l (46-oz.) enamel-lined cans with plain tin ends. After packing, the products were stored for 18 weeks at 23.9°F and the rate of ascorbic acid retention and flavor deterioration were measured. The results for the ascorbic acid retention are shown in Figure 8. In the metal can there was a rapid initial loss of ascorbic acid due to the dissolved oxygen and headspace oxygen. After this initial loss, the ascorbic acid level stabilized at about 82% of its initial level. In the Tetra Brik®, a rapid initial loss of ascorbic acid occurred, likely attributable to the dissolved oxygen since there is no headspace in the package. The product in the Tetra Brik® package continued to lose ascorbic acid at a linear rate between 6 and 18 weeks until the study was terminated because the product reached a point of borderline acceptability. At that point, the ascorbic acid retention was about 69%. The data from this study would tend to indicate that the shelf-life expectancy for a ctirus product in the Tetra Brik® package should not exceed five months, and perhaps four months would be a more prudent figure. The attainable shelf life will, of course, be dependent upon conditions under which the product is stored. At temperatures above 23.9°C a shorter shelf life should be expected.

4.5 Dehydrated Juices

Attempts to prepare dehydrated citrus juices date back to the mid-1940's when freeze drying was investigated, followed by an investigation into puff drying in a vacuum shelf dryer (87). Interest in the production of dehydrated citrus juices later led to the development of the continuous vacuum belt dryer and the foam-mat process. Other attempts to dehydrate citrus juices employed drum drying and spray drying. More recently, a filter-mat process (88) was described and touted as a method suitable for the dehydration of sensitive products such as citrus juices. The filtermat dryer is described as a four-stage process that utilizes a combination of spray drying and belt drying with heated air; the latter is accomplished on a stainless-steel screen mesh conveyor. Attiyate (89) recently described the process that utilizes microwave energy for evaporation of moisture. The process is said to rank between spray drying and freeze drying from an economic standpoint. A commercial operation exists in France where preconcentrated orange juice with a total solids content of 63% is dehydrated. The process is said to provide a quality product that exhibits good retention of color, flavor, and aroma.

In most processes for the production of dehydrated citrus juices, a concentrated juice is blended with a drying aid which

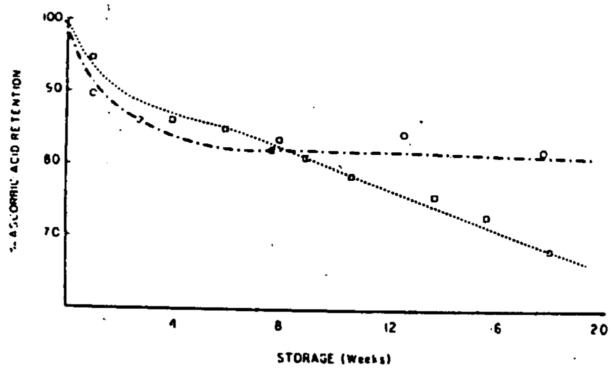

Figure 8. *Ascorbic acid retention in single-strength orange juice stored at 23.9°C ((○) 1.36-l metal can; (□) 1.0-l foil-lined Brik (aseptic))*

is usually a carbohydrate. The drying aid is generally added in order to improve the drying rate, to inhibit product from sticking to the walls and belts of dryers by raising the "sticky point," to reduce hygroscopicity, and to maintain flowability in the dry powder. The drying agents normally employed are the maltodextrins; however, sugar, low D.E. corn syrups, modified food starches, and other carbohydrates of high molecular weight are also used at times. For foam-mat drying, methylcellulose is used to help create a stable foam and to create a porous structure to enhance the rate of drying.

Vacuum belt drying and spray drying are the two processes most widely used today for the dehydration of citrus juices. In neither process is it commercially feasible to produce a dehydrated juice without the addition of a drying aid, although 100% orange juice has been produced with the continuous vacuum belt dehydrator (42,43). This product is extremely hygroscopic and very temperature sensitive. As a result, the product "cakes" or hardens if exposed to moist air or to temperatures much above 24°C. The product is also subject to browning if not stored at refrigerated temperatures. Dehydrated citrus juices are produced on a vacuum belt dryer at Crystals International, Plant City, Florida, and are items of commerce.

Moy and Spellmann (90) recently reported on the economic feasibility of vacuum puff freeze drying of tropical fruit juices and nectars. They considered the process economically feasible if production rates were 250,000 or 1,000,000kg of dried nectar base per year (two plant sizes) with an assumed level of 35% sucrose (wet weight basis) blended with the juice or puree before dehydration. One assumption made in their study was that a marketing share equivalent to 0.5% of the annual orange juice volume in the U.S. was attainable.

Gupta (90) developed a process for spray drying an aqueous orange juice slurry that contained a carbohydrate drying aid. With his process, he produced free-flowing orange juice powders that contained as much as 60% orange juice solids by weight. There are citrus juice powders commercially available today that contain as much as 50% w/w fruit solids, the remainder of the dry weight being contributed by carbohydrate drying aid.

Because of the need to employ drying aids, the economics for most dehydrated citrus juices are not favorable enough to warrant their large scale usage. Generally, they are employed in specialized areas or in products that contain juice contents in the range of 10-15% by volume of reconstituted product. The flavor qualities of the dehydrated juice products are not equivalent to those of the juices prior to dehydration. Usually the flavor quality is degraded to some degree and this is dependent upon the conditions employed in the drying process (3). If the drying aids are not carefully selected, they can lead to the development of additional off flavors during the dehydration process and the storage of the free-flowing powder.

Berry et al. (54) evaluated foam-mat dried instant orange juice and determined that its flavor was acceptable over 26 weeks when stored at 21.1°C. At 29.4°C flavor changes were observed after two to four weeks with samples in the pH range of 4 to 6. The flavor stability of the instant orange powder was directly related to pH when stored at 29.4°C. Stability was improved by using more acidic juices, addition of acid, or removal of sugar.

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